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(71) Applicant(s) University of Salford  (Incorporated in the United Kingdom)  School of Prosthetics and Orthotics, Statham Street, SALFORD, M6 6PU, United Kingdom	(52) UK CL (Edition O) G1N NAEB NENM N1D6 N1P N19B2G5 N30P9 N4A N4B N7H2 N7N N7T1A U1S S1041 S2185
(72) Inventor(s) Glyn Harvey Heath Benham Hersvi Kenneth William Taylor	(56) Documents Cited GB 2284482 A GB 2176610 A EP 0410197 A1 WO 84/04820 A1 Measurement Science & Technology Vol4 1993 (UK) Peter J Kyberd & Paul H Chappell "A force sensor for automatic manipulation based on the HALL effect" pages 281-287, especially pages 281-282
(74) Agent and/or Address for Service Potts, Kerr & Co 15 Hamilton Square, BIRKENHEAD, Merseyside, L41 6BR, United Kingdom	(58) Field of Search UK CL (Edition N ) G1N NACA NACNI NAEA NAEB NENM NENR NENX Online : WPI

(54) A transducer

(57) A transducer for use in contact with a part of the human body to control a prosthesis comprises a Hall-effect sensor 2 mounted in a housing 1, and a magnet 4 separated from the sensor by resilient means 3 between the sensor and magnet to allow relative displacement of those two elements. As shown the resilient means is a piece of plastics or rubber, e.g. foamed polyurethane, but arrangements using springs are envisaged. Fig. 5 shows such a transducer fitted in a recess 32 in a socket 30 of a prosthesis fitted to a forearm 20 which has been amputated below the elbow. Contraction of muscle 22 displaces the skin 24 to move the magnet. An arrangement for sensing rotation of the forearm within the socket is also described (Figs. 6, 7).

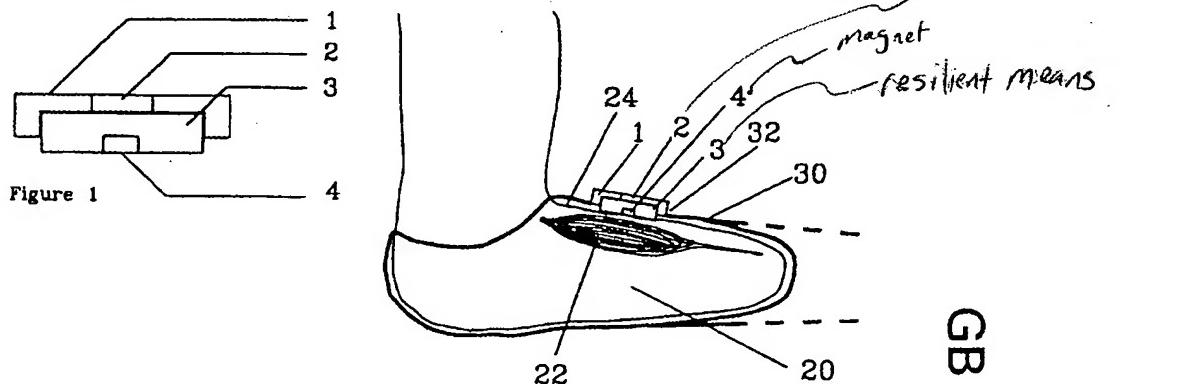


Figure 5

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

The claims were filed later than the filing date within the period prescribed by Rule 25(1) of the Patents Rules 1995

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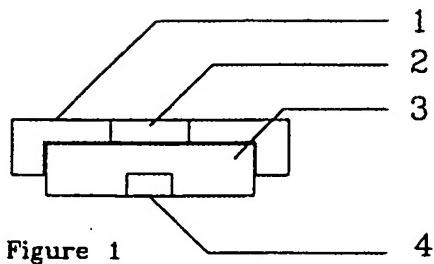


Figure 1

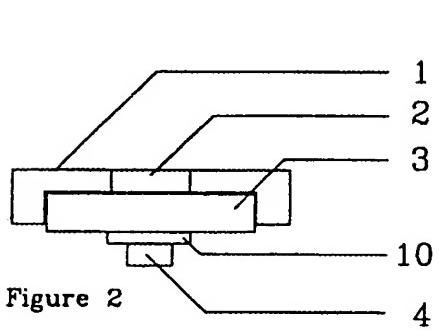


Figure 2

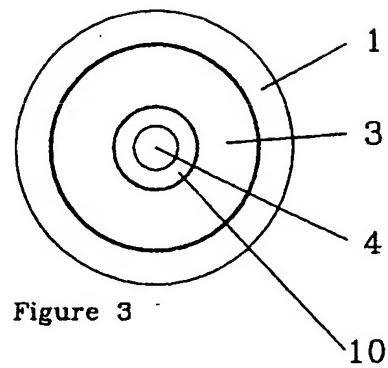


Figure 3

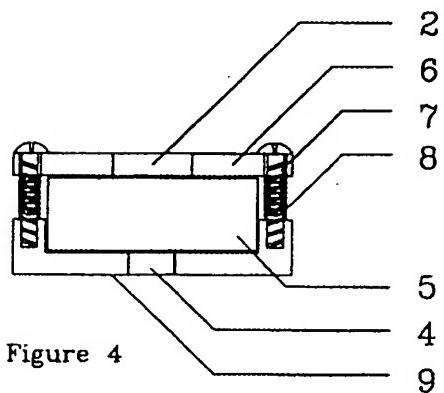


Figure 4

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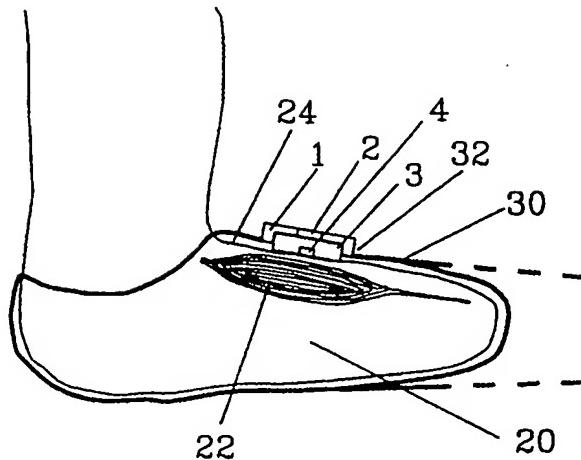


Figure 5

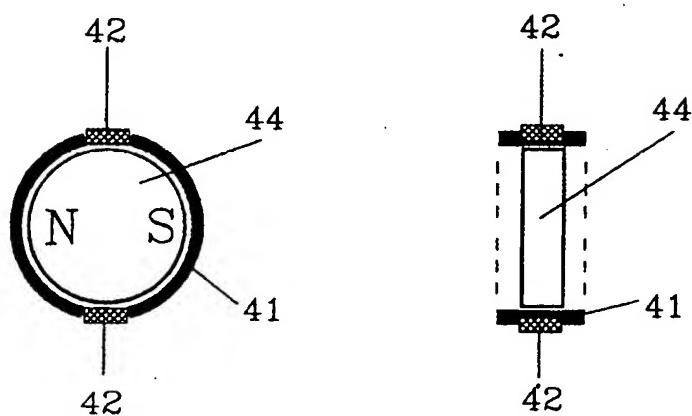


Figure 6

Figure 7

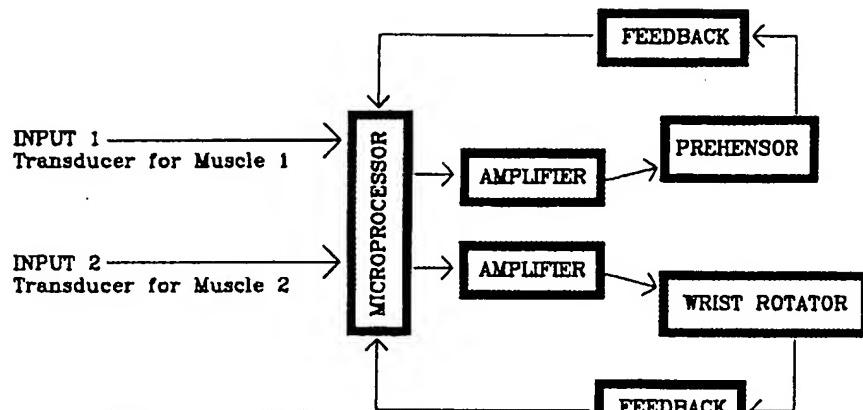


Figure 8

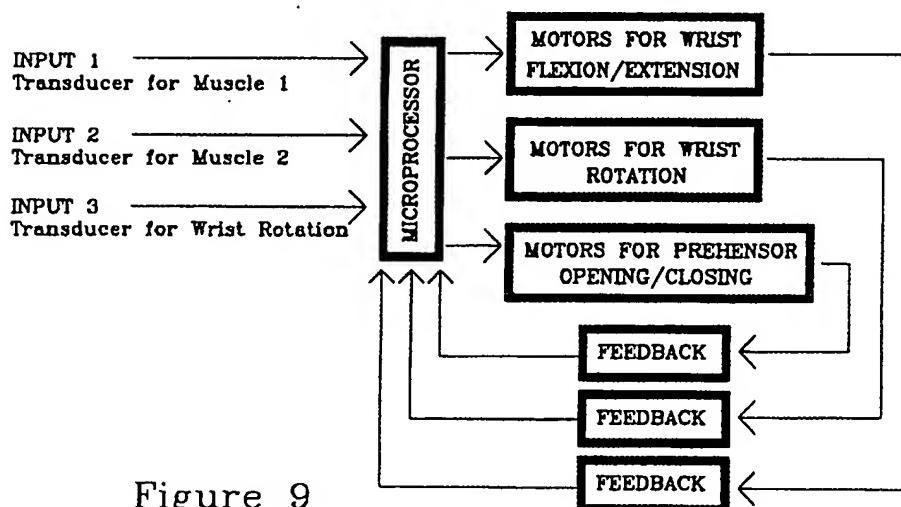


Figure 9

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A TRANSDUCER

The present invention relates to a transducer and in particular, but not exclusively, to a transducer for sensing skin displacements in response to, for example, muscle contractions.

As background to the present invention, the case may be considered of an amputee who has had an arm amputated below the elbow. The residual forearm of such amputee may be fitted with a below-elbow prosthesis comprising a forearm and a hand. Commonly, the hand may be controlled to provide limited movement such as opening and closing (prehension). The hand may simply be in the form of a double hook or may be more complicated, possibly including 'fingers' and a wrist.

A long established problem in the field of prosthetics is how to control a prosthesis, including such a below-elbow prosthesis. Similar control problems arise with all controllable prostheses.

German Patent 895044 Wilms from 1953 (first published in 1949) discloses a control mechanism of a below-elbow prosthesis. The residual forearm is moved within a socket portion of the prosthesis and, through a lever and bowden cables, switches an electric motor on, off and in reverse to control opening and closing of an artificial thumb and finger.

The Bulletin of Prosthetics Research of fall 1966, pages 30-51, "The French Electric Hand", Lucaccini et al., discloses an embodiment of the prostheses described in the aforementioned German Patent 895044. The described prosthesis is improved in that a pneumatic transducer is used to switch the electric motor in

response to movement of the residual forearm.

Other developments in the field of prosthesis control has evolved myoelectric control or "bio-electric control" techniques, which are used to sense the very small electric currents generated in muscle/tissue. These currents are amplified some ten thousand times and then used to control, for example, electric motors in a prosthesis. Disclosures of such techniques is, for example, given on pages 23-25 of the December 1982 edition of the U.S. publication "Engineering in Medicine and Biology Magazine" and on pages 421-424 of the Journal of Bone and Joint Surgery. However, the sensors used are complicated, expensive and necessitate a direct electrical connection to the body. Further, the sensors are not robust and must be adjusted frequently.

As further background, a Hall-effect device is a commonly available semiconductor integrated circuit package which produces an output in response to ambient magnetic flux. The device may be a simple on/off switch or may give an output proportional to the strength of magnetic flux. One particular device is a Linear Output Hall-effect Device which produces a substantially linearly variable output voltage proportional to strength of magnetic flux.

European Patent Application EP-A-0549855 (Otto Bock Orthopädische Industrie Besitz and anr.) published in 1992 discloses the use of a Hall-effect device to measure the relative rotary angular displacement of a magnet attached to a shaft. The shaft forms part of a knee joint of a lower limb prosthesis.

An aim of the present invention is to provide an improved transducer for measuring, for example,

physiological activity (movement of the human or animal body).

According to the present invention there is provided a transducer comprising:

a Hall-effect device;

a magnet;

separating means disposed between and separating said Hall-effect device and said magnet, said separating means being yieldable to operatively allow said magnet to move with respect to said Hall-effect device and/or vice versa, said separating means being resilient to operatively tend to return said Hall-effect device and said magnet to a predetermined separation.

One advantage of the present invention is that the transducer may be manufactured as a self-contained unit. The transducer may also be electrically isolated from a surface whose movement is to be detected using the transducer. Further, the surface is not polluted by the transducer. The transducer may be sealed in a protective coating for use in hazardous or harsh environments.

Movement of, for example, a human body may be measured by placing the transducer such that the body moves the magnet with respect to the Hall-effect device or vice versa. Preferably, the Hall-effect device is held substantially stationary with respect to the object to be measured and the magnet moved by the object. This reduces fatigue in any wires attached to the Hall-effect device. Unlike the prior art, there is no need for the magnet to be fixedly attached to moving part to be measured.

The Hall-effect device may be a simple switch but preferably has a proportional, ideally linear, output. Thus, an accurate output signal may be produced depending

upon the relative separation of the magnet and the Hall-effect device.

The magnet may be any suitable source of magnetism including an electromagnetic coil or, preferably, a permanent magnet.

The separating means may take any suitable form and is preferably disposed to allow displacement of the magnet and Hall-effect device only toward and away from one another. The displacement is preferably linear, although a small degree of tilt is acceptable.

In one preferred embodiment, the separating means comprises a resiliently compressible material forming a layer between the magnet and the Hall-effect device. The magnet and/or the Hall-effect device may be mounted on or in this layer. A suitable material is rubber or a foam material such as a polyurethane foam.

In another embodiment, the separating means comprises a more complicated structure, such as a structure including substantially rigid support members for receiving said Hall-effect device and said magnet; and a resilient biasing means such as a spring or springs disposed therebetween. An alternative structure may comprise a flexible sheet enveloping a fluid such as a liquid which is displaceable into a reservoir biased to return the fluid from the reservoir. The skilled person will envisage a number of further alternate structures.

The transducer described herein will find application in numerous fields: wherever a displacement transducer, pressure transducer, or electrically isolated switch is required. One particular application is in the fields of prosthetics and orthotics.

It has been observed that an amputee will be able to make muscle movements under the skin of a residual portion of their body when mentally trying to move an amputated portion of their body. Similarly, muscle movements may be observed under the skin of an able body. Therefore, a further aim of the present invention is to provide an apparatus for measuring skin displacement caused by, for example, muscle movements.

Also according to the present invention there is provided a transducer for sensing skin displacements, comprising:

a Hall-effect device;

support means for operatively supporting said Hall-effect device in a substantially stationary position with respect to a human or animal body having a skin displaceable due to, for example, muscle movements;

a magnet;

separating means disposed between and separating said Hall-effect device and said magnet, said separating means being yieldable to operatively allow said magnet to move with respect to said Hall-effect device in response to displacement of said skin, said separating means being resilient to operatively bias said magnet generally toward said skin;

whereby said Hall-effect device produces an output variable with displacement of said magnet in response to displacement of said skin.

The support means may simply be a substantially rigid member such as a generally planar plate. Preferably, the support means comprises a socket portion of a prosthesis such that the transducer is operatively retained by, or is an integral part of, the socket portion and the present invention includes such a combination.

This transducer has a number of advantages over other systems in that it is compact, accurate, reliable, easily calibrated, inexpensive to manufacture and has inherent electrical isolation.

It is intended that the present invention can be used in movement analysis of both anatomical or prosthetic limb segments of humans and other animals. It can be used as an adjustable threshold switch as well as a proportional switch. The present invention may be used to control orthoses and/or prostheses, as used by humans and other animals. Other control applications include remote manipulators (such as a robotic arm for bomb disposal or other uses), wheelchairs and environmental control systems for disabled persons.

Further according to the present invention there is provided a method of transducing movement generated by physiological or kinematic activity of a human or other animal body, comprising applying a transducer incorporating a Hall-effect device and magnet directly to said human or other animal body and using the voltage originating from the output of the transducer in response to said movement to control a remote system and/or a prosthesis or orthosis and/or for movement analysis.

The present invention will be described further, by way of example, with reference to the accompanying drawings, in which:

Fig. 1 is a schematic illustration of a first embodiment of a transducer according to the invention;

Fig.s 2 and 3 are a schematic illustrations of an alternate arrangement of the transducer of Fig. 1;

Fig. 4 is a schematic illustration of a second

embodiment of a transducer according to the invention;

Fig. 5 is a schematic illustration of a below-elbow prosthesis including a transducer;

Fig. 6 is a top view of a transducer for measuring relative rotation;

Fig. 7 is a side view of the transducer of Fig. 6;

Fig. 8 is a schematic illustration of a control system taking input from a muscle transducer and a rotation transducer; and

Fig. 9 is a schematic illustration of a control system taking inputs from two muscle transducers and a rotation transducer.

With reference to Fig. 1, a first embodiment of the transducer comprises a Hall-effect device 2 mounted in a housing 1 separated by a resilient compressible material 3 from a magnet 4.

In this embodiment, the magnet 4 is attached to and recessed in the compressible material 3. The compressible material may be of any suitable type, such as rubber or plastics material, e.g. a polyurethane foam.

In operation, movement of the magnet relative to the Hall-effect device will generate an output. The magnet may be moved directly or indirectly via compression of the compressible material. In the preferred embodiment, the output is a voltage which varies as to the square root of the separation. This output thus measures or represents the displacement caused by movement, and can be further processed so as to control external systems. The output may be coupled to a microprocessor control system. By noting the output signal achieved for maximum and minimum displacements, the transducer may be readily calibrated when installed

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and recalibrated as required.

As shown in Fig. 1, the housing 1 is provided with a cylindrical lip portion 5, used to retain the compressible material 3.

In an alternate arrangement of the transducer, shown in side view in Fig. 2 and in top view in Fig. 3, a plastics material supporting disc 10 of larger diameter than the magnet 4 is provided between the magnet 4 and the compressible material 3 or the magnet is placed in an aperture in the supporting disc. In use the plate 6 of the device of Fig. 2 is kept stationary by it being held rigidly within the socket of the prosthesis. Hence adjustment causes only plate 9 to move. With regard to other applications of this transducer, plate 6 would be held against or within a structure that would sufficiently resist movement. This supporting disc inhibits tilting movement of the magnet 4.

For applications involving movement analysis of the skin in response to, for example, muscle movements, the transducer may be held in place by a simple band or bandage. Hall-effect device 2 is kept at a substantially stationary predetermined separation from the skin by using a spacer or other suitable means. Such spacer may be in the form of a plurality of legs.

In Fig. 4, a mechanically calibrated (zeroable) transducer is illustrated. The transducer comprises a Hall-effect device 2 located in a recess of an annular support member 6 and a magnet 4 mounted in mounting member 9 which is adjustable in position relative to support member 6 via screws 7. Support member 6 has a plurality of apertures through which screws 7 extend without engagement. Support member 6 is urged away from

mounting member 9 by springs 8 and is held captive by the heads of screws 7. In use the plate 6 of the device of Fig. 2 is kept stationary by it being held rigidly within the socket of the prosthesis. Hence adjustment causes only plate 9 to move. With regard to other applications of this transducer, plate 6 would be held against or within a structure that would sufficiently resist movement. In use, the screw heads are freely displaceable away from the support member 6 when the mounting member is displaced against the bias of the springs 8.

The range of displacement of the magnet 4 with respect to Hall-effect device 2 can be varied between limits by use of the small screws 7 and springs 8, radially orientated so as to connect top section 6 to retaining section 9. A compressible material 5 may be provided between top and bottom sections 6 and 9. The compressible material 5 inhibits the sections from tilting or twisting along a horizontal axis when pushed together. Although a small degree of tilt is acceptable, it is more commonly desired to measure only linear displacement.

Referring now to Fig. 5, a transducer similar to that shown in Fig. 1 is illustrated in use on a human forearm 20. The transducer is mounted in a recessed portion 32 of a socket 30 of a below-elbow prosthesis. For simplicity, only the socket portion of the prosthesis is shown.

Once the socket 30 is mounted on the forearm 20, the compressible material layer 3 is slightly compressed and holds magnet 4 against skin 24. Contraction of muscle 22 displaces the skin 24, which displacement is measured by the relative movement of magnet 4 with respect to

Hall-effect device 2. The output may be used to control, for example, a prehensor motor to open and close a hand portion of the prosthesis.

An advantage of the present invention is that a muscle or muscle groups normally used to control, for example, hand prehension, may be used to control prehension of a prosthesis. Therefore, it is much easier for an amputee to learn to use the prosthesis since the prosthesis can be designed to respond to corresponding natural body movements.

A second advantage is that the transducer may be integrated with a prosthesis so that an amputee merely needs to fit the prosthesis to a residual limb to operate, rather than attach the transducers to the forearm and then insert the forearm with the transducers on it, into the socket.

A further advantage is that the transducer is electrically isolated from the skin, leading to increased safety. The transducer may also be sealed for use in harsh or hazardous environments.

Another advantage is that the transducer is mechanically simple, leading to low manufacturing costs and increased reliability. The output from a Hall-effect device may be interfaced with a control circuit and does not require large scale amplification. The transducer is relatively inexpensive compared, for example, to a myo-electronics sensor. Further, myo-electronic techniques usually require two sensors since muscles work in pairs with one to pull 'up' and another to pull 'down'. The present transducer can be used to monitor both 'up' and 'down' by measuring just one of the muscles, thus halving the number of sensor sites.

Figures 6 and 7 show a transducer for measuring rotation. This rotation transducer may be used in combination with any of the transducers of Figures 1-4. A diametrically magnetised cylindrical magnet 44 is rotatable mounted within a housing 41. One or more Hall-effect devices 42 are provided on or in the housing 41 to measure the relative angular position of the magnet. One of the housing 41 and the magnet 44 may be secured to a prosthesis and the other attached to an amputee's residual limb such as a forearm. An amputee will usually wear a close fitting cotton or silicon rubber sock over a residual limb and conveniently attachment may be made to this sock. Thus, rotation of a forearm 20 within a socket of a prosthesis 30 may be measured. This measurement may be used, for example, to control a wrist rotator in a below-elbow prosthesis corresponding to a full range of anatomical movement.

Fig. 8 shows schematically a control system taking inputs from a muscle transducer such as described with reference to Fig. 5 and a rotation transducer such as described with reference to Figures 6 and 7. These inputs are processed to control a prehensor motor and a wrist rotator respectively.

Fig. 9 shows a control system taking inputs from two muscle transducers and a rotation transducer. These inputs are used to control a below-elbow prosthesis to give prehensor and rotator control as above. Further, the provision of a second muscle transducer to measure appropriate muscle action allows the control of a third function such as wrist flexion/extension. The number of transducers may be increased as required to measure and if desired to control a large number of anatomical actions.

CLAIMS

1. A transducer comprising:  
a Hall-effect device;  
a magnet; and  
separating means disposed between and separating  
said Hall-effect device and said magnet, said separating  
means being yieldable to operatively allow said magnet to  
move with respect to said Hall-effect device and/or vice  
versa, said separating means being resilient to  
operatively tend to return said Hall-effect device and  
said magnet to a predetermined separation.
2. A transducer as claimed in claim 1 wherein said  
separating means is disposed to allow displacement of  
said magnet and said Hall-effect device substantially  
linearly toward and/or away from one another.
3. A transducer as claimed in any preceding claim  
wherein said separating means comprises a layer of  
resilient compressible material.
4. A transducer as claimed in claim 3 wherein said  
magnet and/or said Hall-effect device is mounted on or in  
said layer.
5. A transducer as claimed in any preceding claim  
wherein said separating means comprises a substantially  
rigid support member for supporting said Hall-effect  
device or said magnet.
6. A transducer as claimed in claim 1 or claim 2  
wherein said separating means comprises first and second  
substantially rigid support members for supporting said  
Hall-effect device and said magnet, respectively, and a  
resilient compressible biasing means disposed between

said support members.

7. A transducer as claimed in claim 6, wherein said resilient biasing means comprises one or more compression springs.

8. A transducer as claimed in any preceding claim wherein said Hall-effect device is a switch having states dependent upon relative separation of said magnet and said Hall-effect device.

9. A transducer as claimed in any preceding claim wherein said Hall-effect device has an output proportional to relative separation of said Hall-effect device and said magnet.

10. A transducer as claimed in any preceding claim wherein said magnet is a permanent magnet.

11. A transducer as claimed in any preceding claim wherein said transducer is provided with a protective and/or electrically isolating outer layer.

12. A transducer as claimed in any preceding claim wherein said transducer is a self contained unit.

13. A transducer for transducing physiological activity into an electrical output, comprising:

a Hall-effect device;

support means for operatively supporting said Hall-effect device in a substantially stationary position with respect to a human or animal body having a displaceable portion;

a magnet;

separating means disposed between and separating said Hall-effect device and said magnet,

said separating means being resilient to operatively bias said magnet generally toward a displaceable portion of a body,

      said separating means being yieldable to operatively allow said magnet to move with respect to said Hall-effect device in response to displacement of a displaceable portion of a body;

      whereby said Hall-effect device produces an output variable with changing separation of said magnet and said Hall-effect device.

14.     A transducer as claimed in claim 13 wherein said support means comprises a spacer.

15.     A transducer as claimed in claim 15 wherein said spacer comprises a body portion having a plurality of legs protruding substantially perpendicularly therefrom.

16.     A transducer as claimed in claim 15 wherein said support means is operatively held against a skin by a strap, band or bandage.

17.     A transducer as claimed in claim 13 wherein said support means comprises a socket portion of a prosthesis.

18.     A transducer as claimed in claim 17 wherein said transducer is operatively retained by, or is an integral part of, said socket portion.

19.     A controllable prosthesis comprising a transducer as claimed in any preceding claim.

20.     A method of transducing movement generated by physiological or kinematic activity of a human or other animal body, comprising applying a transducer incorporating a Hall-effect device and magnet directly to

said human or other animal body and using said voltage originating from the output of the transducer in response to said movement to control a remote system and/or a prosthesis or orthosis and/or for movement analysis.

21. A transducer substantially as hereinbefore described with reference to the accompanying drawings.

22. A controllable prosthesis substantially as hereinbefore described with reference to the accompanying drawings.

23. A method of transducing movement substantially as hereinbefore described.

<p><b>Patents Act 1977</b></p> <p><b>Examiner's report to the Comptroller under Section 17</b></p> <p><b>(The Search report)</b></p>	<u>16</u>	<p><b>Application number</b></p> <p>GB 9513454.0</p>
<p><b>Relevant Technical Fields</b></p> <p>(i) UK Cl (Ed.N)      G1N (NACA, NACNI, NAEA, NAEB, NENM, NENR, NENX)</p> <p>(ii) Int Cl (Ed.)</p>	<p><b>Search Examiner</b></p> <p>M G CLARKE</p>	
<p><b>Databases (see below)</b></p> <p>(i) UK Patent Office collections of GB, EP, WO and US patent specifications.</p> <p>(ii) ONLINE: WPI</p>	<p><b>Date of completion of Search</b></p> <p>1 DECEMBER 1995</p>	<p><b>Documents considered relevant following a search in respect of Claims :-</b></p> <p>1 TO 19, 21, 22</p>

**Categories of documents**

X:	Document indicating lack of novelty or of inventive step.	P:	Document published on or after the declared priority date but before the filing date of the present application.
Y:	Document indicating lack of inventive step if combined with one or more other documents of the same category.	E:	Patent document published on or after, but with priority date earlier than, the filing date of the present application.
A:	Document indicating technological background and/or state of the art.	&:	Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
X	GB 2284482 A	(AUTOLIV KLIPPAN S.N.C.) see especially Figure 1	1, 2, 5-7, 9, 10, 12, 13
X	GB 2176610 A	(DENSA LTD) see especially page 1 line 110 to page 2 line 24	1-3, 9, 10 at least
X	EP 0410197 A1	(IVECO FIAT SpA) whole document	1, 2, 5, 6, 9, 10, 12, 13
X	WO 84/04820 A1	(A T & T) whole document but see especially the paragraph bridging pages 2, 3; page 4 lines 1-10 and page 6 lines 13-34	1-5, 10 at least
X	Measurement Science and Technology Vol. 4 1993 (UK), Peter J Kyberd and Paul H Chappell, "A force sensor for automatic manipulation based on the Hall effect" pages 281-287, especially pages 281-282 and Figure 2		

**Databases:** The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).